## NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

# DATA AND INFORMATION ON GEOTHERMAL PLANTS

by

Dr. Niccolò GENNAI
Larderello S.p.A.

It is not necessary, in my opinion, to narrate again the history of Larderello at this Conference, since this town is already well-known all over the world for its typical resources and for the original applications of endogenous steam in the production of electrical energy and in the utilization of by-products.

However, it may be interesting to draw a brief outline of the most important datas of the research and of the utilization with regard to their costs and to their variations up today.

Diagrams 1 and 2 show drilling costs from 1958 to 1961, and the quantities of steam found from 1951 to 1960. The graphs show a remarkable increase of drilling costs per meter, which affects the costs of each kg of steam. The causes of this variation are self-explanatory, if one considers the origin of the phenomenon. The steam forms certainly in deep strata as a consequence of reactions or exchanges of heat which generate a certain amount of hot fluid, mostly composed of water, which spreads to the upper layers and reaches the surface under particular physical conditions. This steam, through natural channels (fractures), rises to the surface winning the resistance which the strata oppose to its penetration losing energy and often even condensing; most of all, however, it spreads, thus enriching the most porous strata, that is those which offer favorable conditions and low resistance to the penetration.

At Larderello, geology is practically constant and the succession of soils is as follows:
- scaly clay
- anhydrite series
- permian schysts

If the scaly clay layer and the anhydrite series below are especially thick, amounts of steam coming from deep strata may accumulate over a certain period of time, in the anhydrite series. In fcat, caly is almost impermeable and the anhydrite series, much fractured, presents little resistance to the circulation of steam; thus, natural reservers are formed.

Although early drillings at Larderello have discovered steam also in clay-covered layers, it is evident that the anhydrite series is the natural reservoir which, no matter how reached, is almost always in a position to supply steam.

Lowering the resistance which the steam encounters in its spreading by drilling artificial channels, most of the steam will converge toward these channels in order to rise to the surface, thus diminuishing or annulling the diffusion and the enrichment of these strata. In cultivation areas, this has the consequence of requiring deeper and deeper drillings in order to find new steamn and increasing proportionally the cost per drilled meter and the cost of each kg of steam found.

Remarkably deep drillings, up to 3000 m, have been performed at Larderello, with study purposes, but up to now they have given no positive results as far as the findings of steam are concerned. This may be explained by the fact that the anhydrite series was found beneath solid structures, which seem to exclude the possibility of a reservoir.

It is probable, however, that, if the drill could be made to fall upon a natural rise channel, the steam which could be carried to the surface would certainly have much higher pressure and temperature than that which is found in the porous stratum. Consequently, the discovery of stream in deep strata is more a matter of luck than of serious preliminary scientific studies.

From the geological viewpoint the soils crossed by the drill down to 3000 meters are the following:

- scaly clay
- anhydrite series
- permian schysts
- carboniferous schysts

Graph N. 3 shows the characteristic flow - time curve of three wells chosen among the average wells which, in our cultivation areas, are most indicative of the results of the drillings and their decrease in time. From these graphs it may be inferred that the life of an average well is longer than 10 years. Table N. 4 shows the kgs of steam measured in the years from 1950 to 1960 at the above-mentioned wells, and their finding costs. Therefore, an easy calculation of the cost of steam for each kWh may be performed by setting the following elements:

| | |
|---|---|
| - average flow | 30,000 kg/h |
| - well's life | 10 years |
| - drilling cost | 100,000 lire per drilled meter |
| - average depth | 800 meters |

In this case, since every ten years the same amount of steam as ten years before must be found, in order to keep the production of the basin constant, we have:

$$\frac{80,000,000}{15,000 \times 3,760 \times 10} = \text{L. } 0.06$$

| | |
|---|---|
| + 20% = | L. 0.060 |
| | L. 0.012 |
| | L. 0.072 |

Since for each kWh shall be L. 0.072. It must be pointed out that in each well the flow decrease until its exhaustion has nothing to do with the quantity of steam potentially existing in the basin itself. The decrease depends on various causes which reduce the diameter of the well and even choke it, while the amount of steam is practically invariable.

The cost of steam discovered for each kWh produced is a fundamental datum for comparison with other production systems. Table 5 shows the costs of geothermal centrals for the three production cycles. The costs of the

special equipment studied for an early quick utilization of steam in the zones where research is being performed are also added. Such movable equipment (monoblocs), fed by any kind of steam whatsoever - saturated, humid, over-heated - even with remarkable pressure differences, are fed directly and discharged by atmospheric pressure. They may be mounted within 50- 60 days and, though their specific consumption is far higher than that of the two above-mentioned cycles, they have the advantage of requiring little maintenance and personel, and of utilizing immediately the steam found, while waiting for the building of a stable plant, if later surveys shall prove it worthwhile.

This quick examination emphasizes the advantages of geothermal plants when previous studies, drills, surveys of the characteristic of the steam discovered, and utilization projects are performed by specialized personnel.

The genesis of the phenomenon confirms the possibility of finding steam in almost every part of the world. It also shows that this phenomenon lasts through millenia rather than centuries, and that the energy obtained is practically everlasting. Even though it is not possible to state that favorable conditions such as those found at Larderello exist all over the world, it is worthwhile to ascertain whether such possibilities exist.

Our International Relations office reports that geothermal plants have been set up in many countries (Mexico, built by Larderello S;p.A., New Zealand, North America, Russia, Iceland), confirming that steam may be found and applied in many parts of the world.

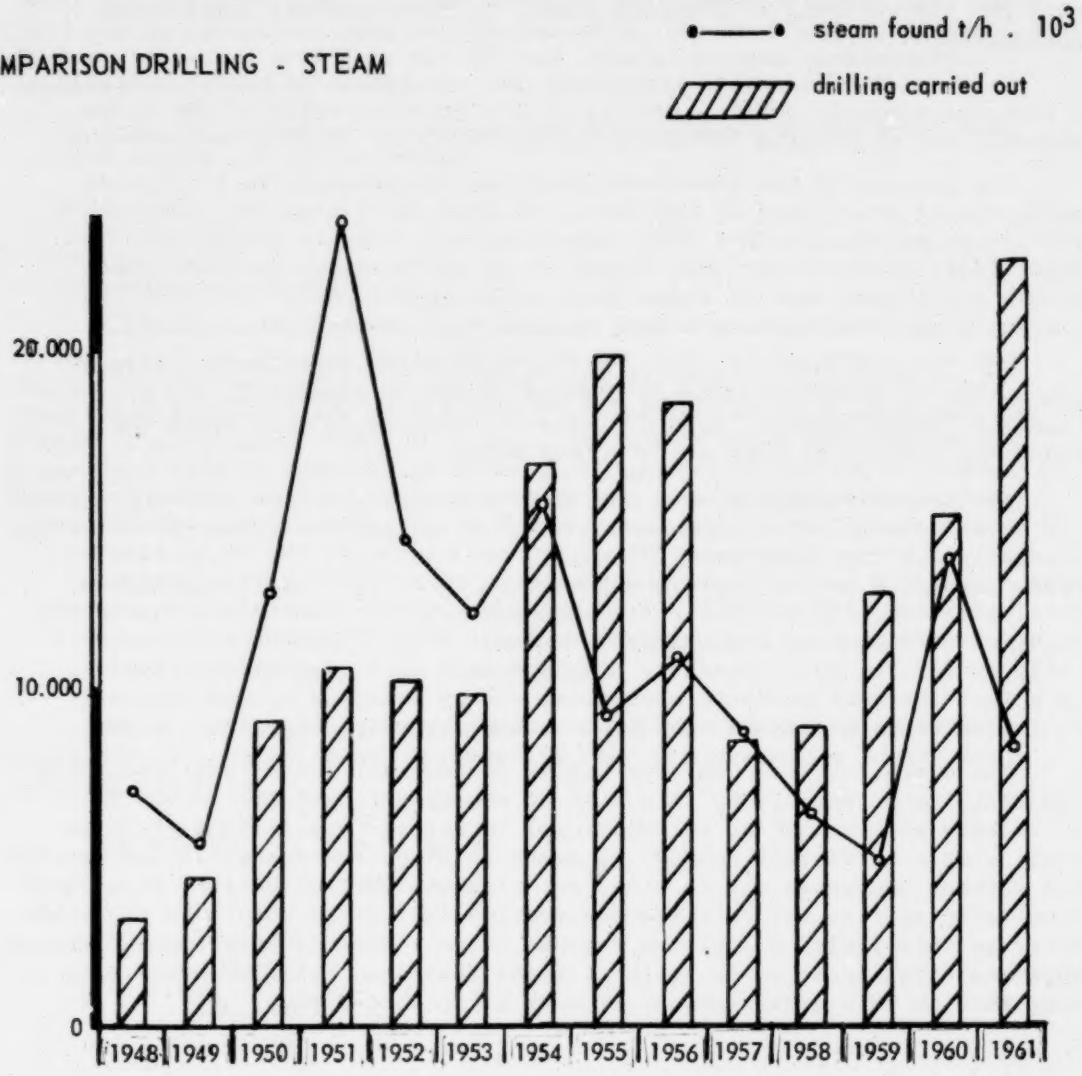
Geothermal energy appears not to have a local Italian interest anymore but an international importance, as a source of energy which may be utilized particularly for the improvement of social conditions of the population of depressed areas. A social improvement implies work opportunities, through industrialization. Independently from local resources, electrical energy may be supplied sufficiently and cheaply; we don't know if geothermal resources may help in filling this necessity, but they may certainly be very useful. It is a fact that, at present, electrical energy obtained by geo-thermal means is much less expensive than that obtained through any other process.

Therefore, it would be very useful to have all the information about the possibility of exploiting this kind of energy all over the world. In order to have such data, an international technical organization might be created, with a sufficient equip, in order to study the possibilities offered by the various countries and to study and plan utilization plants. It is not nationalistic spirit, but only the observation that Italy boasts an undoubted priority in this field, a positive example of achievements thoroughly skilled technicians, that leads us to think it right that the Italians should play a leading role in this organization, if ever it is established.

-

All values of steam and plant costs have been approximated to the nearest round number above.

COMPARISON DRILLING - STEAM




NOTICE: The remarkable differences in the comparison between the meters drilled and the amount of steam found are due to the fact that, in the various years, cultivation and research soundings are both taken into account. Their ratio changes seizeably from year to year.

Fig. 1

COMPARISON DRILLING - EXPENSE

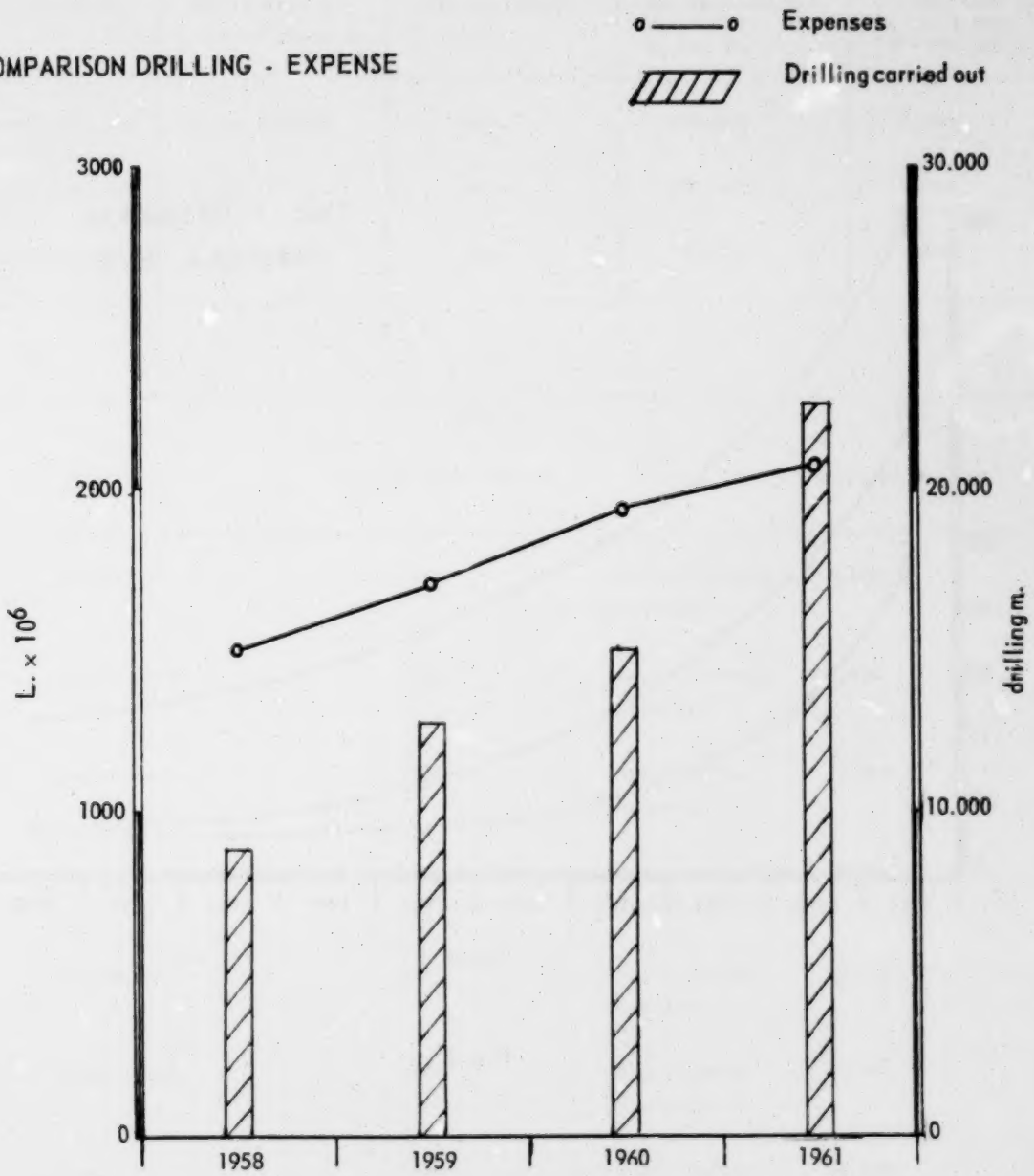



Fig. 2

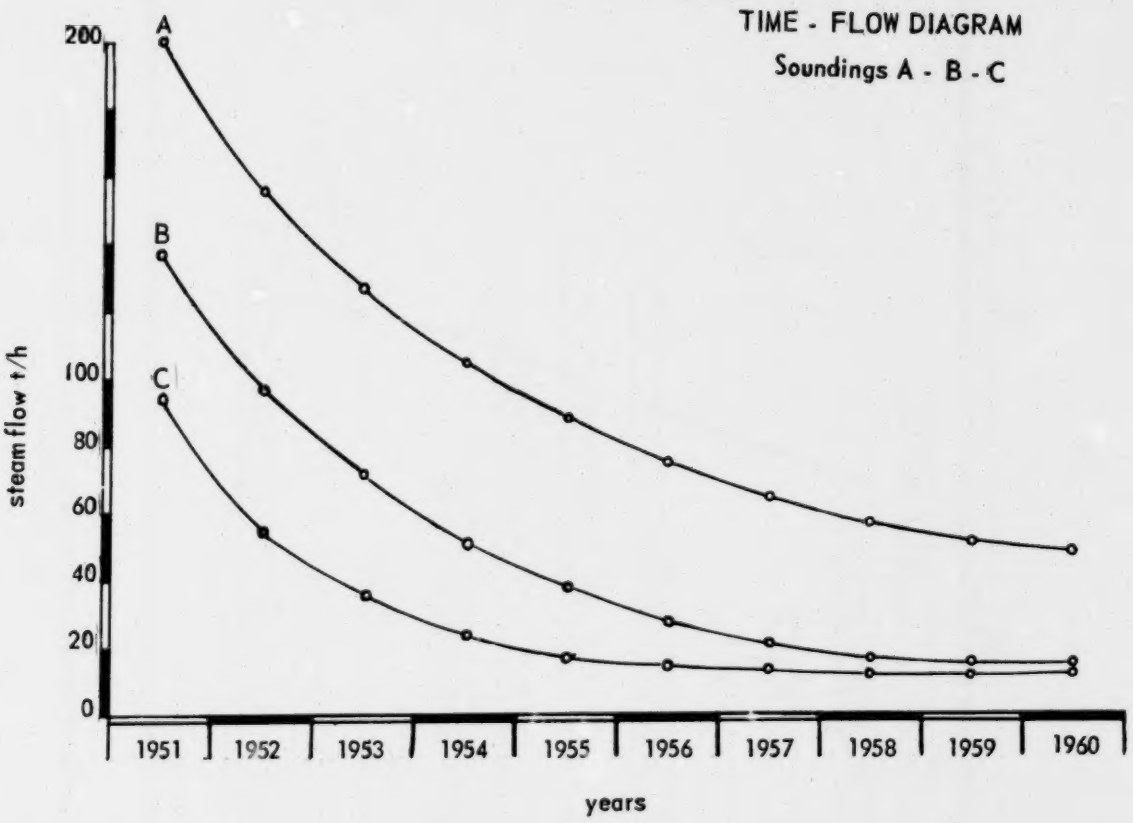

TIME - FLOW DIAGRAM
Soundings A - B - C
steam flow t/h
200
100
80
60
40
20
0
A
B
C
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
years

Fig. 3

COMPARISON OF COST PER METER AND COST PER KG OF STEAM ISSUED BY A FEW TYPICAL DRILLINGS

| SOUNDING | (A) Total issue of kgs of steam in 10 years | (B) Average depth mt | (C) Average cost per drilled mt. L. per mt. | (D) Unitary cost per kg. of steam lire per kg. |
|---|---|---|---|---|
| Drilling (a) | 8,514,720,000 | 800 | 100,000 | 0.009 |
| Drilling (b) | 4,283,640,000 | 800 | 100,000 | 0.018 |
| Drilling (c) | 2,522,880,000 | 800 | 100,000 | 0.032 |

$$D = \frac{B \times C}{A}$$

Fig. 4

| Plant | Year of Construction | Cycle | Net cost per kWh |
|---|---|---|---|
| Larderello n. 2 | 1938 | Indirect vacuum discharge | 6,900 |
| Castelnuovo | 1942 | Indirect vacuum discharge | 6,850 |
| Larderello n.3 | 1938 | Direct vacuum discharge | 31,000 |
| Sasso Pisano | 1958 | Direct vacuum discharge | 70,000 |
| Serrazzano | 1957 | Direct vacuum discharge | 70,000 |
| Monterotondo | 1959 | Direct vacuum discharge | 70,000 |
| Lago | 1960 | Direct vacuum discharge | 70,000 |
| Monoblocco | ----- | Direct discharge into the atmosphere | 40,000 |

1689 E - Nov. 1962 - 1,600